Universität Hamburg

3D Scanners

Intelligent Robotics Seminar

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Agenda

- Introduction
- Point Cloud
- Time-of-Flight 3D Laser Scanner
- Triangulation Based 3D Laser Scanner
- Structured Light 3D Scanner
- Applications of 3D Scanning
- Summary
- Discussion

Introduction

- **Problem**: How to acquire 3D model of different objects or environments?
- **Solutions:**
  - Time-of-Flight (ToF) 3D Laser Scanning
  - Triangular based Laser Scanning
  - Structured Light 3D scanning

Point Cloud

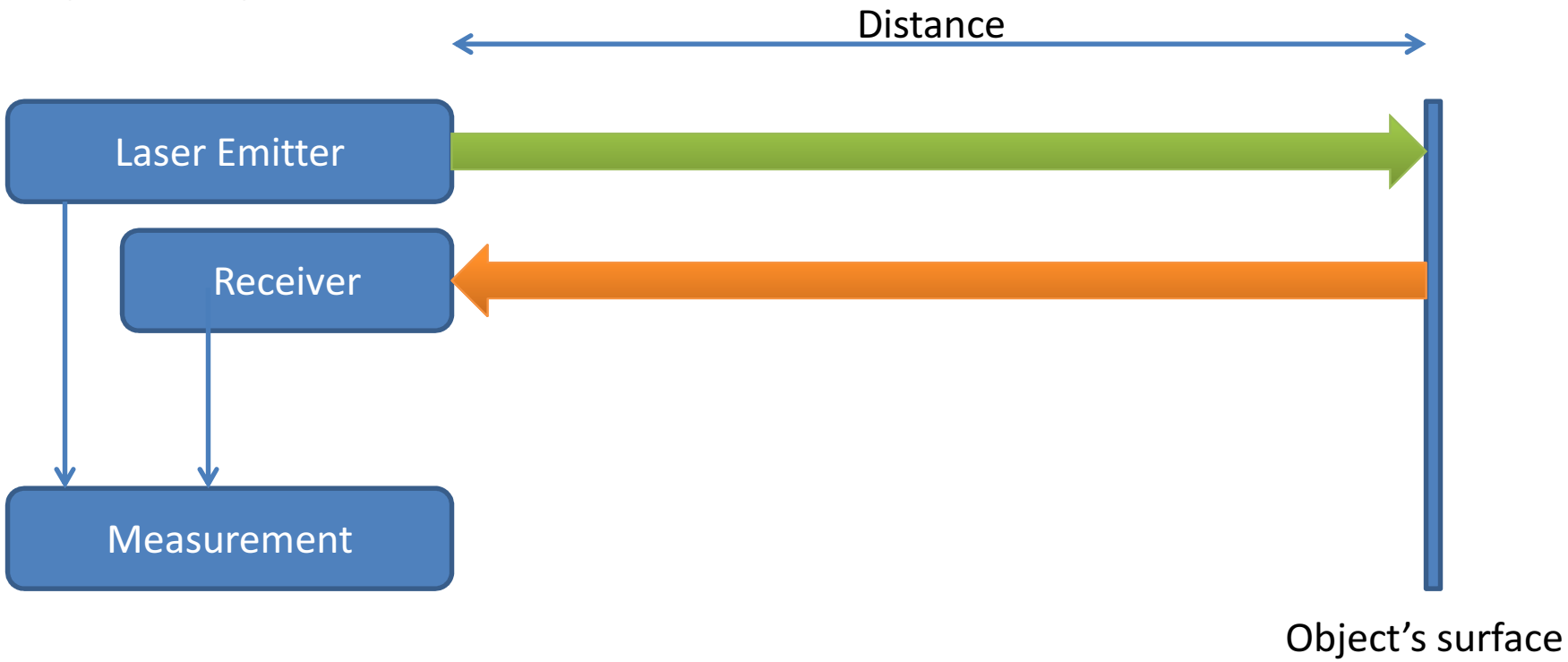
- A data structure to represent multi-dimensional points (including X,Y and Z)

Image from: ddohan.com

Image from: hh-surveys.com

Time-of-Flight 3D Laser Scanner

- Measures the object's distance using ToF principle.



ToF 3D Laser Scanner (cont)

- ***c*** = speed of light (exactly 299,792,458 per meter)
- ***t*** = round trip time.
- Distance = ***c*** x ***t*** / ***2***
- The accuracy of scanner is depended on how precisely we measure ***t***.

ToF 3D Laser Scanner (cont)

- **Second-Time-Around echo:** An echo received after a time delay exceeding one pulse-repetition interval but less than two pulse-repetition intervals.
- Causes range ambiguity.

ToF 3D Laser Scanner (cont)

- **Approaches to avoid range ambiguity:**
  - Appropriate choice of distance.
  - Spatial Multiplexing.
  - Wavelength Multiplexing.

ToF 3D Laser Scanner (cont)

- Spatial Multiplexing:
  - Spatial separation by using multiple scanners with multiple orientations.
- Wavelength Multiplexing:
  - Using multiple wavelengths to operate.

- **Drawback:** Needing multiple scanners.

ToF 3D Laser Scanner (cont)

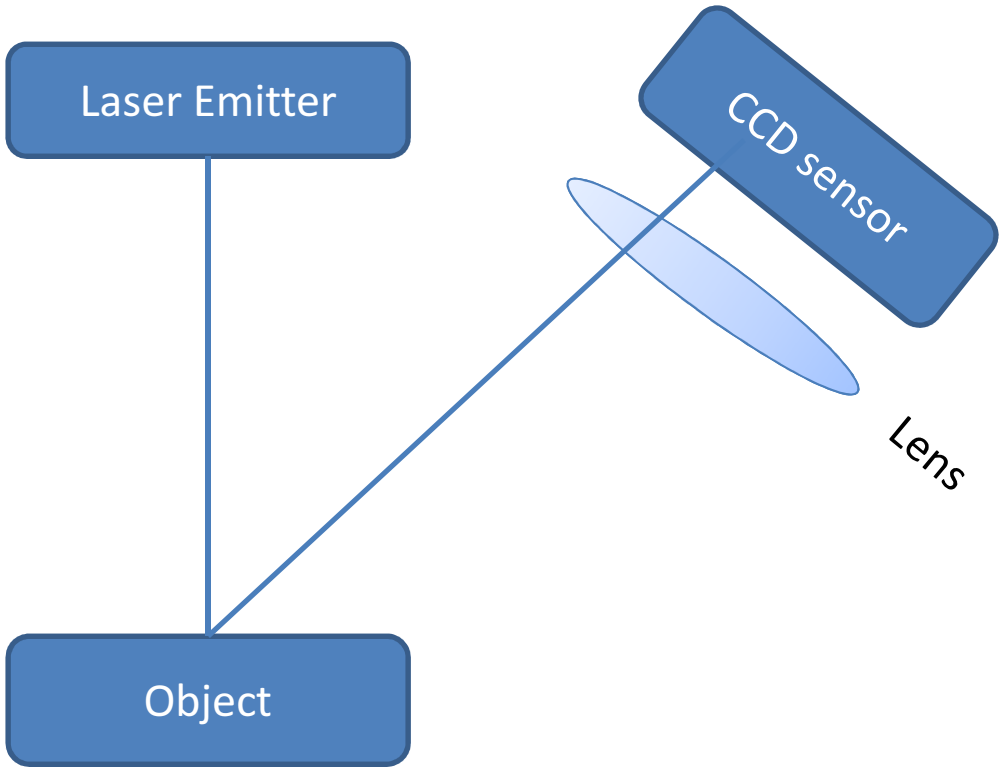
- **Advantage:** Ability to operate on very long distances, a good choice for scanning large buildings and structures.

- **Drawback:** The accuracy of distance measurement is relatively low in order of millimeters.

Triangulation based 3D Laser Scanner

- Calculates the distance from the object by forming a triangle consisting a laser emitter, the object and a camera.
- **A** = Known distance between two corners of the triangle.
- **α =** First angle.
- **β =** Second angle.
- **Θ =** $180 – (\alpha + \beta)$
- The parameters above can fully describe the shape and size of a triangle.

Triangulation based 3D Laser Scanner (cont)



- Location of the laser reflection in CCD sensor changes based on object's surface distance.

Triangulation based 3D Laser Scanner (cont)

- **Advantage:** High accuracy (Tens of micrometers).
- **Drawback:** Limited range of some meters supported.

Structured Light 3D Scanner

- Projects known patterns of light like horizontal bars toward an object and determines the shape and distance of the object by processing the deformation of projected light pattern.

Structured Light 3D Scanner (cont)

- The displacement of a stripe can be converted to 3D coordinates.
  - Identify the stripe by a pattern recognition method.
  - Calculate the 3D coordinates from stripe deformation, e.g. Varying stripe widths on the object's surface.

Structured Light 3D Scanner (cont)

Image from: fab.cba.mit.edu

Structured Light 3D Scanner (cont)

- Reflection causes the light going away from camera, or to be shined in the camera's optic directly.

- **Resolution:**
  - Coating the object
  - Using a diffuser between object and the light source.

Structured Light 3D Scanner (cont)

- How to have a complete 3D shape of the object?

- Putting the object on a turntable and have different markers on object or positioning device, then combine all the scans together.

Structured Light 3D Scanner (cont)

- **Advantages:**
  - High speed of scanning, due to ability of scanning whole field of view at once.
  - Safe for humans because it does not adopt laser technology.

- **Drawback:** Sensitive to environment's light.

Applications of 3D Scanning

- Robotics (Robot's vision).
- Modeling of Different Structures (Bridges, Buildings, Historical Places,…).
- Creating 3D models in Entertainment Industry (Video Games , Movies , …).
- Made to measure fashion retail.
- Etc.

Summary

- Point Cloud.
- Time-of-Flight 3D Laser Scanner.
- Triangulation Based 3D Laser Scanner.
- Structured Light 3D Scanner.
- Applications of 3D Scanning.

References

- IEEE Standard Radar Definitions, IEEE Std 686-1997 (1998).
- High-Speed High-Density Data Acquisition in Airborne Laser Scanning Applications, Peter Rieger and Andreas Ullrich, RIEGL LMS GmbH, 2011.
- Wikipedia, the Free Encyclopedia,
  http://en.wikipedia.org/wiki/3D_scanner
  http://en.wikipedia.org/wiki/Structured-light_3D_scanner
- Pointclouds.org

Thanks for your attention!

Questions and feedback are welcome.